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Fabrication and Investigation on Hardness Behavior of Aluminium Hybrid Metal Matrix Composite (AL8010 Reinforced with Tic and Nanoclay particles)

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Abstract: **-- Composites involve two or more component materials that are generally combined in an attempt to improve material properties such as stiffness, strength, toughness. Composed of a discrete reinforcement and distributed in a continuous phase of matrix, composites are the most successful materials used for recent works in the industry. There has been an increasing interest in composites containing low density and low cost reinforcement. The proposed work was to fabricate and investigate the hardness behavior of Al8010/TiC-Nanoclay composites, The composites were prepared using stir casting method (Liquid Metallurgy route) in which amount of reinforcement such as Hybrid Nano Composites of Nanoclay (MontmorilloniteK10) is varied from 1.5-7.5 wt% in steps of 2 wt%,and Titanium Carbide (TiC) is kept constant for an optimized value of 2 wt%.The prepared hybrid composites of Al8010/TiC-Nanoclay were subjected to evaluate the hardness studies as per the ASTM standard, Nanostructure materials such as nanocomposites provide opportunities to explore new fracture behavior and functionality beyond those found in conventional materials. The presence of small amounts of nanoparticles in metal matrix can improve the hardness of composites. Most of the previous studies carried out on processing of aluminium–TiC composites and aluminium-nanoclay composites evolving their characters .Present investigation has been focused on TiC, also adding Nanoclay for their superior properties to construct the different wt,% of Metal Matrix composite (MMCs), the combination of Aluminium, nanoclay and TiC by using Liquid metallurgical technique to investigate the hardness of the composite..**

Keywords— Hybrid Composite, Nanoclay, Tic, Stir Casting, Brinell hardness.

I. INTRODUCTION

Last few decades majority of research works is focused on nano metal matrix composites (NMCs) due to its unique properties such as, high strength with light weight. But still it is not realized in true application in industries unlike other metal matrix composites (MMCs) due to higher cost of raw materials. The production of nano fillers such as, particles, fibers, rods etc is too costly and even complex roots.

The properties of NMCs along with mechanical, electrical and thermal will be significantly different from MMCs. NMCs are different form of macro particle reinforced MMCs because of very higher ratio of area / surface to volume of the nano-particles. The types of nanofiller reinforcements are nano-particles, nano-flakes, nanotubes, nano-rods, nano-sheets etc. Due to higher surface area of nano-particles, this leads to increase in the magnitude of contact area of interfaces of the matrix and particles. It made these materials properties significantly more than conventional MMCs. NMCs have many advantages such as:

a) Economically producible,
b) Uniform dispersion of nanoparticles in the melt and
c) Strong interfacial strength.

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Advantages of NMCs

The addition of nanoparticle provides substantial improvements such as

- Mechanical properties like UTS, Young's modulus
- Thermal and dimensional stability
- High chemical and corrosion resistance
- Better surface appearance
- Improved thermal and electrical conductivity

A .Nano-clay and its properties

Layered mineral silicate is called clays, and if it is of nano size, then it is called as nanocaly, which depends on its morphology and chemical composition. The different types of nanoclay are: hallovsite, hectorite, kaolinite, betonite and Montmorillonite [11, 12].

Nanoclay (Montmorillonite) is a very soft phyllosilicate group of minerals that typically form in microscopic crystals, forming a clay It is named after Montmorillon in France. Montmorillonite, a member of the smectite family, is 2:1 clay, meaning that it has 2 tetrahedral sheets sandwiching a central octahedral sheet. The particles are plate-shaped with an average diameter of approximately one micrometre. Members of this group include saponite. One of the most common nanoclay forms is montmorillonite (MMT) with a particle thickness of 1 nm and 70 to 100 nm crosswise silica platelets. The choice and extensive use of montmorillonite nanoparticles in previous research is mainly due to the fact that they are commonly available and inexpensive [4].

Sigma-Adrich is manufacturing and supplying various ranges of nano-clay product and their polymer composites. Recently, many research works focused on nanoclay reinforced polymer matrix [5] for different properties. No research work (only this work finds five publications) has been done on nanoclay reinforced MMCs till date.

Nanoclay MontmorilloniteK10

B. Physical properties of Titanium Carbide (Tic)

Titanium carbide is one of the hardest refractory ceramic materials, it is similar to tungsten carbide, Tic has a good conductivity and chemical inert ability to steel and iron. The appearance of Tic is in black powder.

The melting point is about 3200 °C. It is an essential component of cemented carbide with high hardness, corrosion resistance, thermal stability, etc. Also, it is often used in manufacture of wear-resistant materials, cutting tools, mold, metal melting crucible and many other fields.

TiC Particulates (50 microns)

C. AL Based MMCs

Al remains one of material sciences most prized and frequently used substance due to light weight and lower melting point, Al is used as a matrix material in both academician and industries [1]. Al MMCs are used for both structural and non-structural machinery parts. Due to their economic, performance and environmental friendliness they are used as a matrix material for MMCs, which can be used as a weight saving materials [2]. They have outstanding mechanical properties such as, specific strength along with wear resistance and corrosion resistance. Many geometrical shapes of reinforcement are used for MMCs; they are particle, fiber, whiskers etc for strength enhancement. Although carbon fiber has very high strength with low density (ten time stronger than glass fiber) but the cost of carbon fiber is too high (20 times higher) hence researchers found new reinforcement to strengthen the MMCs.The researchers are substituting costly carbon fiber by low cost nano ceramic particle ranging from 10-1000 nm. But the particle sizes of 10 nm to 1000 nm are coined as nanocomposites (NC). But majority of work on Al composites were focused on micro level particle due to their easy availability and easy mixing into the molten melt. [3] But the macro-composites cannot achieve so much strength of carbon based composites, hence, use of nano particle based composites presently triggered, the other problems in macroscopic reinforcement is porosity in the composites.

Aluminum can accommodate a variety of reinforcing agents. When an alloy is used as the matrix instead of pure metal, mechanical properties of composites can be improved by performing different heat treatment operations [9, 10]. The various metal-ceramic combinations some aluminum-based metal matrix composites reinforced with Sic,Tic and graphite are referred to as heat-treatable materials

Al Igniots

Scope of the Work

In this work, the effect of Titanium Carbide (TiC) and Nanoclay (montmorillonite K10) content on the Physical properties of the hybrid composites was investigated. The improvement of physical properties for hybrid composites of Al8010/TiC-Nanoclay will be compared with pure Aluminium Alloy (Al8010). The uniform dispersion of TiC and Nanoclay (K10) in the Al8010matrix will be carried out with proper wettability condition to enhance the properties of composites.

The proposed work is to fabricate and compare the Hardness properties, of Al8010/TiC-Nanoclay composites. The composites were prepared using stir casting method (Liquid Metallurgy route) in which amount of reinforcement such as Hybrid Nano Composites of Nanoclay (Montmorillonite K10) is varied from 1.5-7.5 wt% in steps of 2 wt%, and Titanium Carbide (TiC) is kept constant for an optimized value of 2 wt%. The prepared hybrid composites of Al8010/TiC-Nanoclay were subjected to Hardness studies as per the ASTM standards. Hypothesis of this work in particularly is to optimize the influence of the reinforcements on the properties and also the results obtained will be compared with that of ascast Aluminium Alloy (Al8010).

II. EXPERIMENTAL DETAILS

2.1. Matrix Materials

2.1.1. Aluminium Alloys

Al 8010 is a precipitation hardening aluminum alloy, containing magnesium and silicon as its major alloying elements. Al 8010 alloys possess good mechanical properties with ductility and also they are easily weldable alloys. Due to their good properties they find many applications in different fields and areas [6, 7, and 8].

Table1; Composition of Aluminium alloy Al8010

Components	Weight (%)
Silicon	(0.4- 0.8)
Iron	(0- 0.7)
Copper	(0.15- 0.40)
Manganese	(0- 0.15)
Magnesium	(0.8- 1.8)
Chromium	(0.04- 0.35)
Zinc	(0- 0.25)
Titanium	(0- 0.15)
Other elements	(0.05- 0.15)
Aluminium	Remaining

2.1.2. Reinforcements (Nanoclay and Titanium Carbide)

Nanoclay (MontmorilloniteK10) and Titanium Carbide (TiC) 50 microns are used as reinforcement in a Hybrid form ie. Nanoclay is varied from1.5, 3.5, 5.5 and 7.5 wt, % and TiC is being constant to an optimized value of 2 wt, %.

2.1.3. Wettability (Degassing and Slag Removal)

To overcome wettability, and to remove the dissolved gases from liquid and then to add Cover flux to decrease of contact angle and surface tension forces using and also to enhance the properties of composites. Hexachloroethane is immersed into the molten metal to remove the hydrogen and dissolved gasses, as in figure (a) After degassing process, calculated (1wt.%) amount Cover flux (Scum Powder) as in figure (b) is poured into the molten aluminium alloy and hand stirred for 60 seconds, then the floating slag is removed, after with retains the purest form of Molten Al8010 Alloy.

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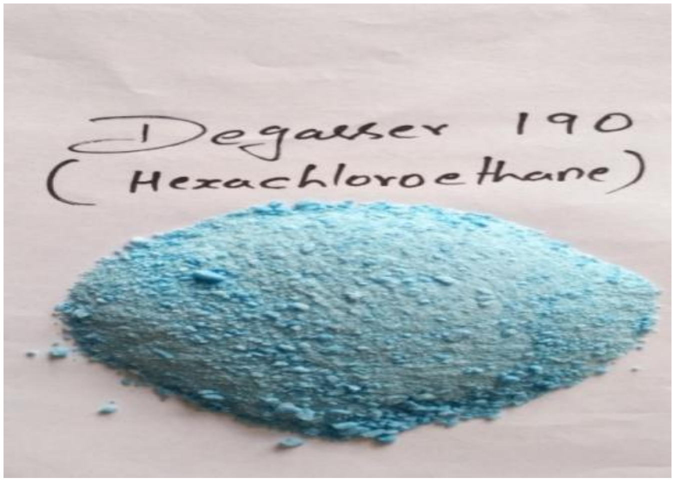


a) Degasser (Hexachloroethane)

b) Cover Flux (Scum Powder)

2.2. Composite Preparation

2.2.1. Preparation of the composites

Al8010 alloy was used as matrix alloy and TiC , Nanoclay (montmorillonite K10) was used as reinforcements for preparation of composites. TiC is kept constant of 2wt. % to an optimum value and Nanoclay of 1.5 – 7.5wt. % (interval 2 wt, %) Al/TiC/Nanoclay Nano Hybrid composites. The Graphite crucible containing with the stainless steel impeller was coated with alumina. The charge of about 3.5kg was melted under 1wt, % of TiB_2 (Master Alloy for Grain refinement) for high purity. The Degasser 190 was also used to create inert atmosphere to avoid oxidation and to remove the slag from the Al8010 slurry cover flux powder is used.

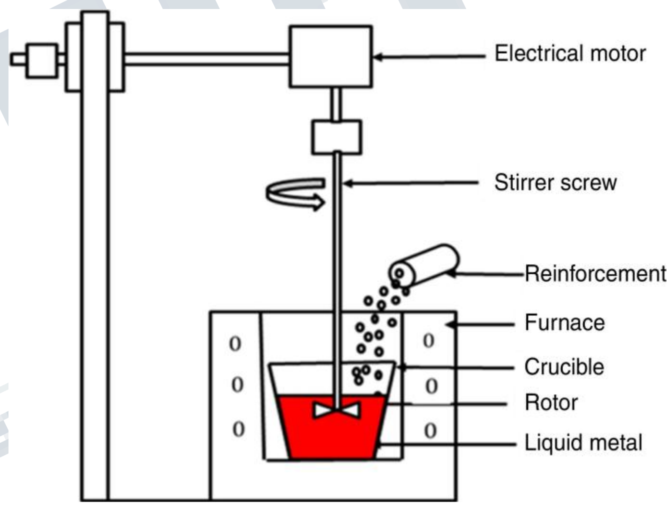
The impeller speed was maintained at range between 400-600 rpm. During stirring, the preheated TiC and nanoclay was poured in to the molten metal for mixing uniformly. Once stirring was completed, the Crucible was moved from the furnace and melt was poured into the pre heated cast-iron and mild steel die.

2.2.2. Composite furnace details

The furnace used to prepare the Al MMCs was of the side tilting type. It has an alumina coated graphite crucible fitted in the middle portion, into which the metal is placed for melting. On the top portion, a motor attached stirrer is placed and there is a provision made for lowering down of the stirrer into the furnace through the lid.

Central control panel is provided with all the necessary electrical connections, indicators, controllers, etc.

The furnace is electrically heated 3-phase resistance type with a 12 KW capacity fitted with three pairs of 14-gauge kanthal Al grade heating coils. The maximum temperature of the furnace is 1100 °C and fitted with integrated differential digital temperature controller.



Stir Casting

2.2.2. Stirrer Detail

The stirrers of centrifugal type with three blades were welded at semicircular shape and 120° apart. It is coated with alumina and this is necessary to prevent contamination of the non-ferrous melt into which the stirrer will be dipped during

Stirring Temperature	Stirring Speed	Stirring time (seconds)
675°C	500-600 rpm	600 seconds

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2.2.3. Casting;

Casting is a manufacturing process by which a liquid material is poured into mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected out of the mold to complete the process.

2.2.4. Machining

It is process carried out after the casting process is completed; it is used to remove the excess material from the test bar. Machining is the process of removal of excess of material from the work, which is carried out in order to get down the casted specimen to the required specifications by making use of lathe. In this case the specimen will be fitted to a chuck which is rotating whereas the tool is stationary which is fitted to the tool post. By giving required depth of cut the material will be simultaneously removed from the work.

III. HARDNESS TEST

3.1. Brinell Hardness Test (ASTM E10)

We conducted hardness test by using Rockwell and Brinell hardness testing machine in accordance with ASTME10 standard. Place the specimen on the anvil so that its surface will be normal to the direction of the applied load and Note down the type and size of the indenter. Adjust the weights on the plunger according to the type of test whether it is Rockwell or Brinell shown in charts by load selection disc and Keep the lever at position "A". Raise the anvil and test specimen by turning the hand wheel clockwise so that specimen will push the indenter and the small pointer in the dial starts to move, Continue to raise the specimen until the small pointer comes to SET (red spot) position. This indicates that the minor load of 10kgf is acting upon the specimen. Turn the lever from position "A" to "B" slowly so that the total load is brought in to action without any jerks. The indenter starts to go down into the specimen and the long pointer of the dial gauge reaches a steady position when indentations complete Take back the lever to position "A" slowly. Read the position of the pointer on the selected scale. Which gives the number as per the selected type of test turn back the hand wheel and remove the specimen? Carry out the same procedure to obtain three independent hardness determinations on each specimen.

3.2. Hardness Test(Brinell Hardness Number)

<table>
<tr><td colspan="2">Hardness Test Samples of Hybrid Nano Metal Matrix Composite

A)As cast Al 8010 Alloy</td></tr>
<tr><td>
B) Al8010 + 2% TiC + 1.5% Nanoclay(K10)</td><td>
C) Al8010 + 2% TiC + 3.5% Nanoclay(K10)</td></tr>
<tr><td>
D) Al8010 + 2% TiC + 5.5% Nanoclay(K10)</td><td>
E) Al8010 + 2% TiC + 7.5% Nanoclay(K10)</td></tr>
</table>

IV. RESULTS

Brinell Hardness Number (BHN) for Al8010andAl8010/TiC/Nanoclay (K10) Hybrid Nano Composites The brinell hardness test results of AL8010 and AL8010/Tic/Nanoclay hybrid composite are follows, Table 4.1;

Sl No	% of Reinforcements	BHN
1	Al 8010	43.533
2	Al8010 +2% Tic +1.5%Nanoclay	60.9391
3	Al8010 +2% Tic +3.5%Nanoclay	66.831
4	Al8010 +2% Tic +5.5%Nanoclay	76.9549
5	Al8010 +2% Tic +7.5%Nanoclay	69.3085

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Table 4.1 presents the average of three hardness (BHN) reading values of alloy and its hybrid nano composites. Figure 4.1.1.shows the graphs for the effect of reinforcement content on Brinell hardness number of the processedAl8010 alloy and Al 8010+ (1.5 -7.5 wt% of Nanoclay and 2wt.% of TiC) hybrid nano composites. Each value of hardness is an average of 3 readings (experiments).

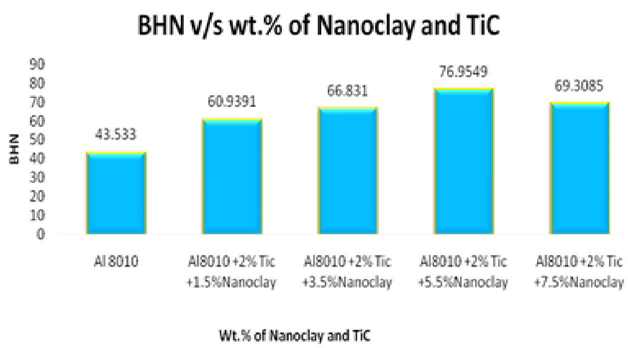

Fig.4.1.1. The effect of Wt. % of TiC & Nanoclay on Hardness of Al8010/ TiC/Nanoclay hybrid Nano composites

From the graphs is noticed that improvement in hardness was achieved up to 7.5 wt % Nanoclay Clay and optimum of 2 Wt% TiC. As the Nano clay content is increased from 0% to 5.5 %, and TiC kept to an optimum value of 2 wt% the hardness increased by about 43.43%.The increase in hardness can be attributed to the presence of hard Nanoclay and TiC particulates that impart strength to the matrix alloy, thereby providing enhanced resistance to indentation or scratch. From the graph it is noticed that there is a sudden decrease in hardness of the composite at 7.5 wt. % of Nanoclay reinforcement and 2wt. % of TiC, which is said to be decreased by 9.93 %, it's due to the clusters formation and mainly because of dislocation and de-bonding between the matrix and reinforcement.

V. CONCLUSION

Al8010+Nanoclay + 2 wt% of TiC composite was prepared successfully using liquid metallurgy techniques by incorporating the reinforcing particulates. The obtained casting was uniform without any blowholes or any defects in the casting by visual inspection and it also reveals good bonding among matrix and reinforcement particles, which yields better load transfer from matrix to reinforcement material. The Nano clay content is increased from 0% to 5.5 %, and TiC kept 2wt% of optimum value the hardness is increased. It is noticed that there is a sudden decrease in hardness of the composite at 7.5 wt. % of Nanoclay reinforcement and 2wt. % of TiC. At 7.5wt% of Nanoclay and 2wt. % of TiC particle reinforcement identifies few clusters formation, dislocation and de-bonding mechanism, which led in drop out of the hardness properties of this composites.

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